Climate Change Impacts on Drinking Water Security: A Comparative Study in Australia's Remote Central Australia and Torres Strait Islands

Nina Lansbury

Julia Bradford

Sandra J. Creamer

Geoffrey Evans

Climate Change Impacts on Drinking Water Security: A Comparative Study in Australia's Remote Central Australia and Torres Strait Islands

Abstract

Aboriginal and Torres Strait Islander communities are well adapted to the many different environments in which they have lived for thousands of years. However, their environments and communities are highly vulnerable to impacts of anthropogenic climate change, including increasing threats to the security of drinking water supplies. Climate change is intensifying the significant social and economic disadvantage Australia's Aboriginal and Torres Strait Islander communities face from poverty, poor housing, and poor health including high exposure to infectious and other diseases. Lack of sufficient safe, clean, drinking water could force Aboriginal and Torres Strait Islander people to leave their homelands, adding the hardship of displacement to the devastating legacies of colonisation, with profound consequences for people's identity, culture, and rights as Traditional Owners. As governments, industry, and communities are making decisions about the end use and allocation of finite water resources, including for new agribusiness, gas and mining developments, which might exacerbate an already stressed system, Aboriginal and Torres Strait Islander leaders and organisations in the Barkly and Torres Strait Islands are becoming actively engaged in water security issues, and they are demanding a strong voice over the governance of water resources. This case study highlights that, for Aboriginal and Torres Strait Islander communities, a precautionary approach to water policy links sustainable water management with community demands for effective adaptation and mitigation strategies and aspirations for climate justice.

Ethics Approval Statement

None required

Keywords

Climate change, drinking water, remote, Aboriginal and Torres Strait Islander, water security

Australia is experiencing climate change, with the long-term warming trend meaning most years are now warmer than almost any observed during the 20th century. Meanwhile, increasing intensity of heavy rainfall events, increasing extreme fire weather and a longer fire season across large parts of the country, and rising sea levels which risk inundation and damage to coastal infrastructure and communities, are causing traumatic outcomes for people in many parts of the continent (Bureau of Meteorology and CSIRO, 2022). These trends threaten the short-term wellbeing and long-term liveability of many Australian communities over the last decade (Abram, 2021).

While such disasters have received high levels of media publicity and government responses, many of Australia's Aboriginal and Torres Strait Islander communities living in climate-vulnerable locations remain disproportionately exposed to climate extremes in heat, rainfall, and drought, with this disproportionate exposure predicted to increase with climate change over the coming decades (Standen et al., 2022). As these exposures become more acute, health, safety, and the liveability of some communities are under threat (Healthy Environments and Lives Network, 2021; Memmott et al., 2022; Standen et al., 2022). Climate change multiplies disadvantage to Australia's Aboriginal and Torres Strait Islander communities that already suffer acute structural socioeconomic disadvantage, with particularly urgent action needed to address housing and energy infrastructure (Lowitja Institute, 2022). This was described in a report that sought to capture Aboriginal and Torres Strait Islander voices on climate change:

> The rain and storms don't come when they used to. We don't get the cold weather rains anymore. It's only a little light winter storm. The first cheeky storm doesn't come any more. It used to come in September and October, but we don't get it anymore. We don't get the monsoon anymore, but this year there was a big turnaround. It came back as a flood, the wrong way. It washed everything out…
>
> - Warumungu respondent, Tennant Creek, NT (Lansbury et al., 2023)

In this changing climate, water security is a pertinent concern in many remote Aboriginal and Torres Strait Islander communities who seek long-term access to reliable supply of clean, safe, drinking water. The agency that coordinates the United Nations' agency on water and sanitation**,** UN-Water, defines water security as:

> The capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability (UN-Water, 2013, p.1).

Given this situation, this research sought to understand and document remote water security challenges in a changing climate to augment the published evidence that could contribute to addressing these needs.

Background

This section provides further in-depth context to the issues contributing to water insecurity, particularly in remote locations. It outlines the link between climate change, drinking water and health, and then describes water use patterns of consumption in some remote communities that are affected by water insecurity.

Climate, Drinking Water, and Health

Australia's Aboriginal and Torres Strait Islander communities are the most exposed communities to the impacts of climate change (Hall, 2020; Memmott et al., 2022; Quilty et al., 2022). A combination of geographic location, poor quality housing, lack of appropriate infrastructure, economic disadvantage, and other factors contribute to heightened impacts from climate events. This includes heat stress, floods, storms, drought, wildfires, changing abundance and distribution patterns of pests, disease vectors and pathogens, and sea-level rise in coastal communities, which together are cascading across the socio-ecological systems in which Aboriginal and Torres Strait Islander communities live (Malhi et al., 2020).

Adverse physical health effect from climate change is a threat multiplier to communities that already experience high rates of premature mortality, and chronic levels of morbidity, including heat-related disorders, vector-borne diseases, food and waterborne diseases, respiratory disorders, and exacerbate chronic diseases including heart and kidney disease (Healthy Environments and Lives Network, 2021).

For many Aboriginal and Torres Strait Islander peoples, their capacity to live on their traditional homelands is already compromised through remoteness and general financial capacity. Climate change is making the liveability of many Aboriginal and Torres Strait Islander communities increasingly precarious, and creates new challenges to the cultural, social, and economic wellbeing (including both physical and mental health) of already disadvantaged communities (Hall, 2020; Hall et al., 2022; Healthy Environments and Lives Network, 2021; Race et al., 2016; Standen et al., 2022).

Current climate change predictions of hotter average temperatures and greater evapotranspiration are likely to lead to affect water availability through variable rainfall and rainfall patterns, as well as drive higher water demand by households, industry, and the environment. Increases in the frequency, intensity, and duration of heat waves will further impact water supply and demand. Additionally, more severe and frequent heat waves, storms, cyclones, and other extreme weather events, as well as sea level rise, are likely to damage water supply, treatment and monitoring infrastructure, affecting service delivery, and increasing maintenance costs (NESP Earth Systems and Climate Change Hub, 2018, 2020; Productivity Commission, 2021c).

Lack of sustainable supplies of safe, healthy water adds an additional driver to the already critical public health issues faced by many remote Aboriginal and Torres Strait Islander communities, potentially contributing to higher incidences of infectious diseases including skin infections (boils, sores, scabies and school sores), respiratory infections (upper and lower respiratory tract), and ear, nose and throat infections (middle ear/otitis media, tonsillitis, ear canal and pharyngitis/sore throat) as well as trachoma, conjunctivitis,

gastroenteritis, rheumatic fever, and tooth decay, with chronic kidney disease and rheumatic heart disease outcomes of repeated infection. Threats of water insecurity, inter-linked with poor quality housing, damage to health hardware in the house, overcrowding, and poor physical health make Aboriginal and Torres Strait Islander people living in remote Aboriginal and Torres Strait Islander communities particularly vulnerable to these health problems (N. Hall et al., 2021; N. L. Hall et al., 2021; Memmott et al., 2022; Standen et al., 2022).

Water security is fundamental to sustainable development of human communities, and is critical for ending poverty, improving health and education, reducing inequality, and spurring economic growth (UN, 2015). Access to safe drinking water is a basic human right of all First Peoples; the United Nations recognised this relationship by identifying water security as one of seventeen Sustainable Development Goals (SDG 6), to: “Ensure availability and sustainable management of water and sanitation for all” (UN, 2015).

The UN Human Rights Council reaffirmed that proposition on 14 September 2022 when, in a report to the General Assembly, Special Rapporteur Pedro Arrojo-Agudo, noted that,

> States must put in place the necessary means to ensure that Indigenous peoples enjoy their human rights to safe drinking water and sanitation, inclusive of an intercultural dialogue that is respectful of their ancestral worldviews, knowledge and practices (UN, 2022, p.1).

Furthermore, First Peoples have asserted that the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) principle of self-determination is the foundation of water justice for their communities (Robison, 2018). Australian Aboriginal and Torres Strait Islander people have declared that water security is intrinsically linked to their human rights, and to their spiritual, cultural, environmental, social, and economic wellbeing.

Aboriginal and Torres Strait Islander people’s knowledge about water on their customary estates is critical environmental knowledge that is essential for survival and

resource security. This knowledge, and the responsibilities that flow from it, are critical elements of Aboriginal and Torres Strait Islander people's identities and connection with Country (Jackson, 2009). They assert that they must have the right to self-determination as participating players in decisions made regarding water resources (O'Donnell et al., 2021).

Aboriginal and Torres Strait Islander community organisations and leaders, supported by health practitioners, researchers and policy analysts have highlighted the need for state and territory governments, local governments and stakeholders to urgently come together with the water industry to: achieve the goal of every Australian community having access to water that meets the Australian Drinking Water Guidelines, engage Aboriginal and Torres Strait Islander communities in all steps involved in water service delivery, and to work with local communities to "reimagine and reorganise governance and bureaucracy to ensure efficiency, efficacy and accountability" (Vanweydeveld, 2022, p.7).

Understanding Remote Water Consumption

Understanding water security threats requires knowledge of water use and water use patterns. Water consumption in the remote, tropical Aboriginal and Torres Strait Islander communities in the Barkly and Torres Strait Islands follow different usage patterns than water usage in metropolitan areas, such as Brisbane in south-east Queensland. There tends to be a high level of outdoor household water use in remote Aboriginal and Torres Strait Islander communities. For example, Beal et al. (2018) found that outdoor household water use in three Aboriginal and Torres Strait Islander communities (in the Torres Strait Islands, Cape York, and in Central Australia) ranged from 62 to 86% of total average water use (Beal, 2018). The key drivers of high outdoor water use in the Barkly and Torres Strait Islander households (beyond leaks) relate to cleaning, food, and cooling functions, that are essential to maintaining safe and health environments, including cooling of buildings and yards to create an evaporative effect during hot weather, dust control from roads and yards, physical amenity such as gardening, and social amenity including children play spaces and sorry camps and funerals (Beal, 2018; Beal, 2011).

High water use in remote Aboriginal and Torres Strait Islander communities is amplified by inefficiencies and lack of services by local and State/Territory government, and private sector service providers. Beal et al. (2018) reported high levels of severe and prolonged leaking of outdoor fixtures occurred in the communities studied. A later publication reported how at least 18 Central Australian homelands had recurring leaks due to unrepaired water infrastructure, with resultant high costs of water bills. These communities had not received the requested funded from their service provider, so were seeking to raise the funding themselves (CLC, 2020).

Methods

The focus of this research on remote Indigenous communities required central involvement and guidance from authors with experience and cultural understanding of Aboriginal and Torres Strait Islander Peoples. The research topic and design were guided by an Aboriginal co-author and researched by two co-authors with experience in working in partnership with Aboriginal and Torres Strait Islander Peoples in remote communities.

The Aboriginal author, SC, has held leadership roles in governmental and non-governmental organisations that focus on the wellbeing and rights of Aboriginal and Torres Strait Islander Peoples, particularly women. She has spent time on remote Country to provide funded contributions to homeland initiatives to ensure water security that can support self-determined economic activities on Country. This author actively guided, informed, connected and reviewed the researchers' approach, thinking and their work. This approach responds to some of the principles of the South Australian Aboriginal Health Research Accord, namely priorities (where the Aboriginal co-author has raised the concern of remote water from her close engagement in remote homelands and communities, and the need to place a focus on ensuring water security), involvement (of Aboriginal people in developing and translating research), and partnership (where the authorship team and the communities about which they are writing are considered and included in a respectful, mutually trusting relationship) (Morey et al., 2023). This co-author has been conducting

research on remote communities' challenges with water supplies with the final c-author (NL) for seven years, and together they have made submissions to government inquiries and delivering funding directly to remote homeland for water storage (tanks). That non-Indigenous co-author (NL) has been to both case locations for multiple research visits over the past seven years under the guidance of local Aboriginal and Torres Strait Islander collaborators. Another of the non-Indigenous co-authors, (GE), has worked for more than 40 years in community development and land management in the Barkly region, which forms one of the case studies. His relevant experience to this research was his involvement in infrastructure development on community living areas (formerly known as 'town camps'), including water infrastructure failure and wastage, and for outstation communities reliant on groundwater sources and subject to growing heat and environmental stress attributable to climate change.

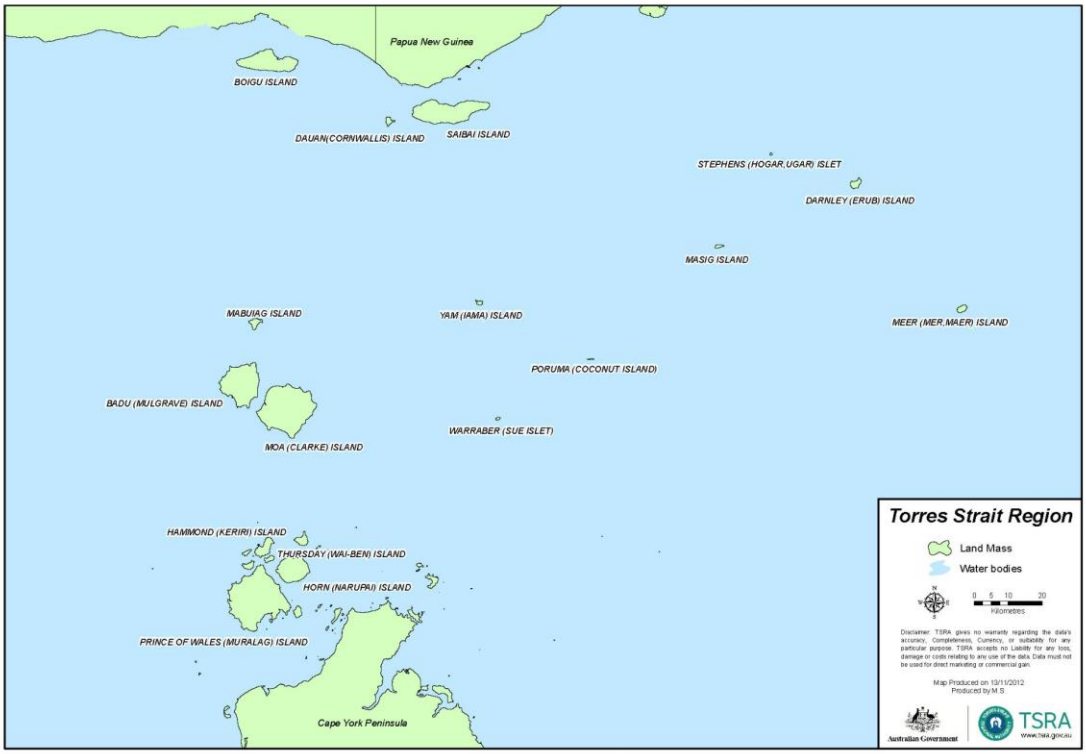
A case study approach was employed to focus the exploration of this topic in specific locations, in order to bring specificity and detail to the issue. Such as focus can prevent broad statements being made across settings that can have both commonalties as well as diverse specific experiences of water insecurity- as described in Hall et al.'s (2021) phrase of drinking water solutions that are 'fit for purpose, people and *place'* [emphasis added]. This approach can both detail the complexity of the context and of the implementation - both of which are critical to climate change discussions (Terrado et al., 2023). The coastal islands of the Torres Strait and the inland desert Barkly region of Central Australia were adopted as the focus, given the diversity of these two regions that are both exposed to significant climate change risks. The case study approach enabled depth and specificity to climate change risk discussions, yet it was also intended that the place-specific findings may be adaptable and relevant to other locations (Priya, 2020).

The Torres Strait Islands are a group of over 274 small islands in the 150km wide waterway separating far northern continental Australia's Cape York Peninsula from the island of New Guinea. They extend over an area of sea 48,000 km^2, with a total land area of

566 km^2. Only 16 islands are populated, as shown in Figure 1. In the 2021 Australian Census, the population was 4,124, of whom over 90% identified as Torres Strait Islander, also known as Zenadth Kes people (Australian Bureau of Statistics, 2021f).

Figure 1

Map of the Torres Strait Islands



Source: National Museum of Australia using TSRA and Australian Government sources (https://digital-classroom.nma.gov.au/images/map-torres-strait).

The Barkly region covers an area of 322,713 square kilometres of tropical semi-arid country located almost in the centre of the Australian continent, 1000 kilometres south the Northern Territory's capital city, Darwin, as show in Figure 2.

Figure 2

Northern Territory, showing the Barkly region

Source: NT Government, Local Decision- Making, Barkly website.

The region has a population of 8,563 people, about 63% of whom identify as Aboriginal or Torres Strait islander (Australian Bureau of Statistics, 2021d). The township of Tennant Creek (Warumungu name, Jurnkurrakurr) is the largest community in the Barkly. Over half (54.5%) of Tennant Creek's population of 3,000 identifies as Aboriginal or Torres Strait islander (Australian Bureau of Statistics, 2022).

Communities across the Barkly include the small township of Elliott (population 290), former mission settlement of Ali Curung (population 396), and communities living on small parcels of land excised from huge pastoral stations, with the larger communities being Amplatiwatja (population 459), Arlparra/Utopia (population 443), Alpurrurulum (population 354), Wutunugurra/Canteen Creek/Epenerra (population 291) (Australian Bureau of

Statistics, 2021a, 2021b, 2021c, 2021e, 2021g, 2021h). There are also 40 family outstation/homeland communities, some permanently occupied, and others having populations (from 0-30 people) fluctuating between seasons and circumstances. All these communities are predominantly Aboriginal and Torres Strait Islander people of the Alyawarre, Warumungu, Warlmanpa, Warlpiri, Kaytetye, and Wambaya language groups.

Literature was gathered as the primary form of data, to compile the contemporary documentation of water insecurity in remote communities in order to provide direction to resolve water insecurity. It was noted that relevant publications would include peer-reviewed academic literature but also relevant policy documents and reports that constitute 'grey literature'. For that reason, a systematic review was not appropriate to adequately locate all relevant sources (Tranfield et al., 2003). Instead, a literature review was adopted to provide an overview of the status and depth of knowledge published on cascading and compounding climate risks; in doing so this method enabled identification of gaps in research and in implementation (Snyder, 2019).

Publications were sought published in the past ten years to ensure recency (2014-2024). Keywords employed to identify risks included drinking water, climate change, Torres Strait, Central Australia, Aboriginal and Torres Strait Islander Peoples, Aboriginal and Torres Strait Islander Peoples, and water security. Sources were located through employing the timeframe and keywords in literature databases including Medline and Scopus, through web browser searches to identify recent and relevant reports, and through expert-identified publications from those working on remote water security research.

The resulting information was reviewed and analysed to identify emerging themes that provide both documentation of the challenges and identification of opportunities to achieve water security in a changing climate. This inductive process was undertaken initially by two of the authors (JB and GE), who separately reviewed and extracted relevant information. They then iteratively engaged with the third author (NL) to discuss the emerging findings and determine the final selection of themes. The Aboriginal author (SC) oversaw the

proposed themes and provided feedback on the write up by reviewing drafts (Maguire & Delahun, 2017). The repeated visits and on-ground familiarity of the authors with the case study locations (GE and NL in the Barkly and Torres respectively, and SC in both locations) enabled a form of *reality check* on the information being reviewed and the emerging themes (Butler et al., 2024).

Results and discussion

This section initially details the specific water security challenges of the two remote case study locations. It then details the four themes that emerged from the analysis of material. The first was the breath of challenges and opportunities facing the goal of water security. The second was a focus on the structural aspects required, while the third describes the political context and responses sought to achieve this security. This final theme features previous collaborations that appear to have effectively improved water security.

Water Security Challenges in the Case Study

Torres Strait Islands

There are 5 geological island clusters in the Torres Strait that affect the drinking water sources and availability: the Top Western Islands comprising Boigu, Dauan, and Saibai which are deltaic alluvial mud deposits over old coral bases; the Western Islands comprising Badu, Mabuaig and Moa Island (Kubin and St Pauls communities) which are continental remnants of the Great Dividing Range that comprised the land-bridge to PNG; the Central Islands comprising Iama (Yam Island), Masig (Yorke Island), Poruma (Coconut Island), Warraber (Sue Island) which are mostly coral cays; the Eastern Islands comprising Mer (Murray Island), Ugar (Stephen Island), Erub (Darnley island) which are volcanic in origin, and the Inner Islands comprising Hammond Island, Muralug (Prince of Wales Island), Ngurupai (Horn Island) and Thursday Island. There are also two Torres Strait communities on the Northern Peninsula Area – Bamaga and Seisia.

In the Torres Strait Islands, water supply is collected from rainwater, weirs, wells, bores, and the ocean. It pumped to water treatment plants and stored before being distributed to communities. The water supplied to most residents of Horn and Thursday Islands is from the Loggy Creek Dam on Horn Island which provides water to Wasaga Village, and via a submarine pipeline, provides water to the Millman Hill Reservoir on Thursday Island (Torres Shire Council, 2022). The outer islands of the Torres Strait have limited water supplies and when reserves are low water is provided through energy intensive, portable desalination units. Monitoring occurs at the water treatment plant along with selected sample sites within the community (Torres Strait Island Regional Council, 2016). Increasing demands and population growth is creating unsustainable water usage (Torres Strait Island Regional Council, 2016).

The Torres Shire acknowledges that current water demand is unsustainably high (Torres Shire Council, 2022) while the Torres Regional Council also acknowledges the likelihood of increased water stress (Torres Strait Island Regional Council, 2016). Torres Strait Island communities located on low-lying islands are particularly vulnerable to sea level rise which threatens to encroach on freshwater aquifers and, along with increasingly severe and more frequent storm surges, will increase coastal erosion. This includes the low-lying islands of Saibai, Boigu, Masig, Warraber, lama and Poruma which are regularly affected by saltwater inundation and subject to coastal erosion (Rainbird, 2016).

Barkly Region, Northern Territory

Water consumed in the Barkly communities is overwhelmingly collected from natural underground water deposits, the inter-connected Wiso, Daly, and Georgina aquifers, which yield water for domestic, stock, and horticultural purposes (Evans, 2016; Kruse, 2013; Randal, 1973). Recharge rates are low, considering that the region's annual rainfall varies between 300 to 600mm across the area, only a very small proportion of it recharges the aquifers. Most is either lost directly to evaporation or utilised by vegetation (Tickell, 2003).

Tennant Creek relies on groundwater from borefields on the Wiso Basin at Kelly Well and Cabbage Tree, south of the town. After it is pumped to the surface, the water is treated to meet Australian Drinking Water Guidelines and stored in elevated storage tanks on hills on the east and western edge of the town. Water extraction from the borefields steadily increased from 1967 to a peak of about 225 ML in 1991–92 before steadily declining to between 100 and 150 ML by 2014 (McPherson et al., 2020). The decline in Tennant Creek water use may correspond to some closures of high water-use minerals processing operations.

The launch of the Water Services Association of Australia's *Closing the Water for People and Communities Gap* report (Vanweydeveld, 2022) highlighted water security challenges facing the remote Alpurrurulum community, which is isolated even within the Barkly context, being located 17 kms from the Queensland-Northern Territory border, and 570 kms to the east of Tennant Creek. Senior leaders of the Alpurrurulum community are concerned about the safety of their bore water, which they say "tastes funny", is unsuitable for showering let alone drinking, and causes itchiness and stomach sickness. Excess fluoride is also a major concern, with the potential for a variety of health impacts due to heavy chemical treatment (Central Land Council, 2022; Cross, 2022).

Aboriginal communities, organisations, and environmental groups concerned about water security from industrial developments across the Barkly have initiated court challenges and public protests about water resources policy and management. The Arid Lands Environment Centre has raised concerns about the absence of legal protections for drinking water quality, lack of institutional separation between water service delivery, policy-making and regulation, and absence of modelling for climate change impacts in Northern Territory water allocation plans or water licensing decisions. (ALEC, 2022a). Concern about over-allocation and potential pollution of groundwater and surface water resources heighten concerns about capacity to meet future drinking water needs, as well as requirements for high priority environmental and cultural water (ALEC, 2022b; Alliance, 2020; NTG, 2021,

2023). Additional publications reinforce future concerns. A report for the AHURI cites data in the Central Australia APY Lands, where rainfall is projected to continue to decline and thus limit the recharge of groundwater water sources on which some remote communities depend for their drinking and other water needs (Lea et al., 2021). This report documents the interrelated nature of water security to support other aspects of health; for example., evaporate cooling systems are common in older homes in the NT are dependent on a reliable and sufficient water supply to operate (Lea et al., 2021). A further AHURI report that included a remote NT community as one of its three case studies cited community respondents' requests for greater collaboration and planning between government agencies respectively responsible for water, housing and power in order to adequately achieve these essential services (Moskos et al., 2024).

Warumungu Traditional Owner, Norman Frank Jupurrurla has echoed community demands across the Barkly for investment in appropriate housing that provides both water security and climate safety:

> A safe house should fit in with our climate, where we are from. What I want on a hot day is a fan, a fridge, safe, clean, reliable water, and shade (Quilty & Jupurrurla, 2021).

Jupurrurla's call for a climate-protective housing has been echoed by health professionals in a range of academic publications (Hall, 2020; Memmott et al., 2022; Quilty et al., 2022).

Theme #1: Overarching Challenges and Opportunities for Achieving Drinking Water Security

Public health risks from drinking contaminated water remain in the remote Barkly and Torres Strait Island communities. Both the Queensland and Northern Territory governments use the Australian Drinking Water Guidelines (ADWG) health-based and aesthetic values as a national framework to describe, manage, monitor, report on, and regulate drinking water

quality. The key performance indicator for the ADWG health guidelines is that there be no detection of E. coli in the distribution system. The aesthetic guidelines require water to be aesthetically acceptable and safe, and able to be used without detriment to fixtures and fittings (Wyrwoll et al., 2022).

Wyrwoll et al (2022) found that exceedances beyond ADWG guideline values, by microbes, nitrates, fluoride, or uranium, are most prevalent in small and remote towns and settlements with less than 1,000 people, and especially remote communities where water quality testing, system maintenance services and notifications of poor-quality drinking water are most lacking (Wyrwoll et al., 2022).

Studies of Western Australian remote Aboriginal communities show that, in many communities, conditions have not improved over the last decade (Office of the Auditor General Western Australia, 2021). These risks exist in small Barkly region homelands, and possibly in some isolated Torres Strait islander communities.

In the Northern Territory, the ADWG are nominated as an objective for water quality in over 400 remote Aboriginal communities and are applied through an agreement between Power and Water Corporation (PWC) and the Northern Territory Department of Health. Approximately 500 homelands/outstations in the NT, with an estimated total population of 10,000 people, are not served by state-owned water suppliers (Wyrwoll et al., 2022). While in the NT, the PWC publishes data on drinking water quality and associated management activities, including priorities for improving water quality in the communities it serves which includes Tennant Creek and some of the larger Barkly communities, adherence to Guidelines is not monitored or publicly reported (Northern Territory Government, 2021). Community leaders have expressed concerns about difficulties accessing this information, particularly of information about treatment of drinking water for real or perceived high levels of salt, calcium and other minerals (Frank Jupurrurla, 2022).

In Queensland, drinking water service providers are co-regulated by the Department of Regional Development, Manufacturing and Water, and Queensland Health. Queensland government regulations require limited monitoring and reporting for many local council water utilities (Wyrwoll et al., 2022).

Climate change impacts are likely to increase the frequency and severity of events that impact on water security, water quality, and health, including damage and degradation of supply infrastructure and higher incidence of climate-sensitive infectious diseases (N. L. Hall et al., 2021). Climate impacts are likely to increase the cost of delivery of reliable supplies of safe water to remote communities (Hall et al., 2022). Table 1 summarises some of the weather-related climate features emerging in the Barkly and Torres Strait Islands that might influence water security.

Changing patterns of disease vectors, attributable to climate change, contribute to patterns of vector-borne and infectious diseases, potentially contributing to health issues, such as diarrhea, vomiting, cramps, nausea, headaches, fever, fatigue, and chronic infections. Chronic infections in early childhood are often linked to vulnerability to other diseases in later life (Hall et al., 2022). It highlights the need to build resilience and adaptive capacity to curtail the physical and chemical impacts of climate change on water infrastructure and to purchase, instal and maintain climate-resilient water infrastructure, minimise the impacts of heat-related stress, the destruction from storms, cyclones, erosion, and salt intrusion on infrastructure. It highlights the need for training and support of local people to maintain infrastructure and implement health protocols (N. Hall et al., 2021; Hall, 2020; Hall et al., 2022; Standen et al., 2022).

Table 1: Weather-related climate features emerging in the Barkly and Torres Strait Islands that influence water security

Weather feature/Region	Barkly	Torres Strait Islands	Water security impact
Temperature & Heat	The region currently experiences hot, dry summers and mild winters. Average temperatures have increased over the past century, with the rate of warming higher since 1960 (NESP Earth Systems and Climate Change Hub, 2020). The number of days above 35°C is projected to increase from 94 in 1995 to 113 in 2030 and 133 by 2090 (under RCP 4.5 scenario, moderate emissions reduction) while the number of days above 40°C are projected to increase from an average of 17 in 1995, to 37 in 2030 and to 49 in 2090 (Watterson I., 2015).	The Torres Strait Islands currently has hot wet summers and warm dry winters (NESP Earth Systems and Climate Change Hub, 2018). Temperatures in the Wet Tropics have been increasing since 1910, especially since 1960. Daytime maximum temperatures have increased by 1.0 °C and overnight minimum temperatures have increased by 1.2 °C. Substantial increases are predicted for mean, maximum and minimum temperature in all seasons.	Increased evaporation will affect supply. Higher demand for cooling and hydration will affect demand.
Rainfall	The average annual number of hot days in Tennant Creek between the period 1959–1988 was 39 increasing to 48 from 1989–2018. The average number of extreme heat days annually (above 44°C) increased from 0 in the period 1959–1988 to 7 from 1989–2018.	A substantial increase in the temperature on the hottest days, with increased frequency of hot days and the duration of warm spells is expected (McInnes, 2015) An historic average of longest run of days in each year with maximum temperature greater than 30°C of 43 between 1981-2010 to 56 (RCP 4.5) and 58 (RCP 8.5) by 2030, and 67 days (RCP 4.5) or 78 (RCP 8.5) by 2050 (CoastAdapt, 2022).	Increased evaporation will affect supply. Higher demand for cooling and hydration will affect demand.
Humidity	Rainfall in Central Australia shows high natural variability. There have also been changes in seasonal rainfall. Tennant Creek recorded an average of 459 mm and 343 mm per annum for the periods (1989-2018 vs 1959-1988), respectively (BoM et al 2019b) (NESP Earth Systems and Climate Change Hub, 2020). Climate models do not agree on projected increase vs decrease, but there is some expectation that the median change for both North and South of the rangelands (with Tennant Creek and the Barkly being in the North) by 2090, under high emissions, is a decrease of 4 % (Watterson I., 2015) p.22	The Torres Strait has a strong monsoonal Wet and Dry season. The mean annual rainfall on Horn Island between 1995-2021 was 1748mm and with 90% of this rain falling during the December to April Wet season, and with a mean of 73.9 days of rain above 1+ mm in the Wet season out of a mean of 95 days of rain 1+ mm rain annually (Bureau of Meteorology). While trends are not clear - it may get either wetter or drier (significant variations between models) - it is predicted that rainfall will become more variable with more intense extreme events. (NESP Earth Systems and Climate Change Hub, 2018) (p.12).	Minimal effect on supply in the Barkly as mot water is derived from groundwater aquifers. Depending on whether rainfall increases or decreases there may be some increase in supply (for tank water and local catchments) but threats to storage and transport may emerge from extreme rainfall events.
Evaporation	Minimal change in the near future and wide variability in projections for longer-term but leaning toward decreased humidity. (Watterson I., 2015)	Significant variability between models but modest increase projected in Wet Tropics (Queensland Government, 2018 #21}	Increased temperatures may have some impact on evaporation rates and therefore supply.
Cyclones	However, models generally show high agreement by 2030 or very high agreement by 2090 on substantial increase in evapotranspiration. Despite having high confidence in an increase, there is only medium confidence in the magnitude of the increase. (Watterson I., 2015).	Despite having high confidence in an increase, there is only medium confidence about the magnitude of the increase (McInnes, 2015).	Evapotranspiration rates impact soil moisture and run-off with significant impacts on water availability for water storage, vegetation growth, including food security

Flooding	Tropical cyclones are projected to become less frequent but they are likely to be more intense storms (Watterson I., 2015) p. 30. Some potential that tropical cyclones may also reach slightly further south. Rainfall produced by tropical cyclones is also expected to increase, particularly the intensity of extreme rainfall events which could increase by about 10% or more per degree of global warming (Watterson I., 2015) p. 30.(NESP Earth Systems and Climate Change Hub, 2020).	Tropical cyclones are the major cause of severe weather in the Wet Tropics. Tropical cyclones are projected with medium confidence to become less frequent with increases in the proportion of the most intense storms. (McInnes, 2015) p.26 It is expected that there will be fewer but more intense tropical cyclones in the future as a result of climate change. (NESP Earth Systems and Climate Change Hub, 2018) P.13.	Strong winds, heavy rainfall, storm surges and severe ocean wave conditions damage infrastructure.
Sea level rise	There is medium confidence that river flood, heavy precipitation and pluvial flood will increase across parts of QLD, NSW, SA, WA, and the NT, including Central Australia (https://interactive-atlas.ipcc.ch/regional-synthesis)	n/a	Flooding will cause damage to infrastructure, raise costs of construction and maintenance.
Drought	n/a	Increasing warming amplifies the exposure of small islands, low-lying coastal areas in the Torres Straits to the risks associated with sea level rise for many human and ecological systems, including increased saltwater intrusion, flooding, and damage to infrastructure (high confidence).	Sea level rise will potentially impact supply on some islands, and cause damage to infrastructure

Theme #2: Essential Infrastructure for Water Security

The challenges of water security in Central Australia was described by a resident living on their remote Country homeland:

> We don't have a proper water supply out here… We access drinking water from a rainwater tank. In a drought, we have to buy 10 litre water cartons from town. We use bore water for washing clothes and for showers. It's salty water straight from the ground. The Government doesn't listen to us…
>
> - Arrernte respondent, Williams Well homeland, NT (NATSIWA & UQ, 2020)

As this quote indicates, access to reliable infrastructure is critical to water security. The health system and water security are compromised when infrastructure such as pumps and collection equipment, pipelines, water treatment equipment, storage tanks, water monitoring equipment domestic health hardware, and electricity supply fail.

Climate change threatens the integrity of water infrastructure, and the capacity to maintain water infrastructure and health hardware. Equipment designed for the climatic conditions of the Barkly and Torres Strait Islands may fail if there is greater heat stress from extended periods of hotter, drier weather, significant fluctuations in soil moisture or temperature, and/or more frequent and severe storms that were not considered in design specifications. Sea level rise, storm surge and flooding are likely to affect water and wastewater infrastructure in low-lying Torres Strait Islands, resulting in water contamination that can impact public health (Infrastructure Australia, 2021). In the Torres Strait Islands saltwater intrusion potentially increases corrosive damage to water infrastructure affecting both surface and ground water resources (Torres Strait Island Regional Council, 2016).

Failing hardware and infrastructure and long lead times and high costs of repairs are common, raising water security risks with unsafe water, unsafe sanitation and lack of hygiene key factors contributing to risk of infection and disease transmission in remote Aboriginal and Torres Strait Islander communities (Hall & Crosby, 2020).

Theme #3: Political responses to Protect Water Supplies in a Changing Climate

Aboriginal and Torres Strait Islander people of the Barkly and the Torres Strait Islands have stated their concerns that, without urgent action, their homelands could become uninhabitable within their own lifetime (Davidson, 2020; Quilty & Jupurrurla, 2021). They have taken strong political action to protect their communities from climate impacts, including impacts on water security. In September 2022, a group of eight Torres Strait Islander people made international legal history after the UN Human Rights Committee found that the Australian government violated its human rights obligations to them through climate change inaction. The complaint, which was the first legal action brought by climate-vulnerable inhabitants of low-lying islands against a nation-state, specifically focused on cultural and ecosystem protections, but has wider implications including potentially water security (Latimore, 2022).

In its response to the Islanders' claims, the Human Rights Commission asked the Australian government to compensate the Islanders for the harm suffered, engage in meaningful consultations with communities to assess needs, and take measures to secure the communities' safe existence on their respective islands (UN Human Rights Office of the Commissioner, 2022)

Aboriginal communities in the Barkly Region (NT), with support from the Land Councils community-controlled health organisations, have asserted that water security is a basic human right that must be recognised in the Northern Territory Strategic Water Plan.(Central Australian Aboriginal Congress, 2022) Along with environmental organisations, and Aboriginal Land Councils, communities have raised concerns about the water security impacts of large-scale agribusiness and mining developments which they assert harms water security across the region. These developments include the Fortune Agribusiness horticulture project at Singleton Station, located 150 km south of Tennant Creek, that the Northern Territory Government granted a 30-year Groundwater Extraction Licence for 40,000 ML/yrs. of groundwater released over 4 stages, free of charge. Communities are

concerned that the substantial water table drawdown from this project will adversely impact a very large area where groundwater levels will decline, with few benefits to local communities (Connor, 2022; Northern Territory Government, 2021).

There has also been strong opposition to the unconventional (fracked) gas mining in the Beetaloo Sub-basin to the north of the Barkly which will potentially adversely impact the Roper, Katherine, and Daly River basins. The gas extraction process requires 50- 60 ML/yd of water per fractured gas well, removed from ground or surface water systems, with potentially hundreds of wells proposed, depending on exploration outcomes. As well as over-use of precious and limited water supplies, there is concern about the risk of groundwater contamination from fracking chemicals. (Alliance, 2020) The Beetaloo area is connected to the Tindal Aquifer which provides water supply to towns, homesteads, agriculture, and the cattle industry and has already had high levels of applications for water extraction licences for horticulture projects in the region.

Theme #4: Effective Collaboration for Water Security

Aboriginal and Torres Strait Islander people have asserted that self-determination and genuine empowerment and participation in governance is a fundamental starting point in achieving the human right to water security. Genuine partnership processes need to include Aboriginal and Torres Strait Islander representation in planning from the outset, and social, spiritual, and customary, objectives and strategies are critical to successfully achieve objectives (Jackson, 2009). Solving complex challenges needs collective effort, with strategies co-designed with affected communities from the start and continued collaboration throughout (Beal, 2019; Kania, 2011).

The Australian government's Productivity Commission noted the slow progress on engagement with Aboriginal and Torres Strait Islander people and communities as a problem that requires reform (Productivity Commission, 2021b). In terms of building resilience and adaptive capacity, the Productivity Commission proposed the following overarching reform principles be embedded in all policy areas, including 'a realistic

assessment of potential climate impacts on water security', 'use of the best available information in decision making', and 'effective community engagement' (Productivity Commission, 2021a).

Two successful collaborative partnerships between Aboriginal and Torres Strait Islander community organisations, local government, state government health, housing, and infrastructure agencies - The NSW Aboriginal Communities Water and Sewerage Program and the Safe and Healthy Drinking Water in the Torres Strait – highlight some valuable lessons. Genuine partnerships empower Aboriginal and Torres Strait Islander communities and organisations to appoint local water operators from the local community and ensure local staff are well supported, with appropriate training on the equipment they operate. Technologies must be fit for place, purpose, and local people, be supported by training programs delivered to the water operators onsite, with ongoing support provided by phone and in person (N. Hall et al., 2021).

Conclusions

There are shared issues affecting water security across both the remote case study locations in Central Australia and the Torres Strait, as well as other communities affected by climate change. These risks include heat stress, severe weather events, and vulnerable infrastructure that require threat mapping, adaptation planning, decision-making, resource allocation, monitoring and evaluation focused on the specific circumstances of each community.

The heightened vulnerability and structural disadvantages of Aboriginal and Torres Strait Islander communities, including those described in this research in the Barkly and Torres Strait Islands, where exposure to extreme climate, sea level rise (in the Torres Strait islands) and severe weather events combine with economic developments to threaten water supply. This is in the context of poorly designed and maintained houses and lack of shade and dust control which drives high household outdoor water use, making urgent action critical as temperatures rise with climate change.

The challenges documented in this research provide evidence for priority action to address housing and infrastructure essential to deliver sustainable supply of clean, safe drinking water to households in a changing climate. Place-based solutions need to be based on inclusive and comprehensive climate adaption with mitigation plans built on genuine engagement and the cultural knowledge of Aboriginal and Torres Strait Islander peoples.

References

Abram, N. J., Henley, B. J., Sen Gupta, A., Lippmann, T.J., Clarke, H., Dowdy, A.J., & Boer, M.M. . (2021). Connections of climate change and variability to large and extreme forest fires in southeast Australia. *Communications Earth & Environment*, *2*(1), 1-17.

ALEC. (2022a). *What's wrong with our water laws in the NT*. https://www.alec.org.au/our_water_regulatory_system_is_failing_in_the_northern_territory

ALEC. (2022b). *Why we're taking the NT Government to court over Singleton*. https://www.alec.org.au/why_were_taking_the_nt_government_to_court_over_singleton

Alliance, P. C. (2020). The Beetaloo Sub-basin: Communities and environment under threat. https://www.protectcountrynt.org.au/beetaloo_overview

Australian Bureau of Statistics, A. (2021a). *Ali Curung 2021 Census Aboriginal and/or Torres Strait Islander people QuickStats* https://abs.gov.au/census/find-census-data/quickstats/2021/ILOC70700101

Australian Bureau of Statistics, A. (2021b). *Alpurrurulam 2021 Census Aboriginal and/or Torres Strait Islander people QuickStats* https://abs.gov.au/census/find-census-data/quickstats/2021/ILOC70700201

Australian Bureau of Statistics, A. (2021c). *Ampilatwatja and Outstations 2021 Census Aboriginal and/or Torres Strait Islander people QuickStats* https://abs.gov.au/census/find-census-data/quickstats/2021/IARE709002

Australian Bureau of Statistics, A. (2021d). *Barkly 2021 Census All persons QuickStats* https://www.abs.gov.au/census/find-census-data/quickstats/2016/SED70004

Australian Bureau of Statistics, A. (2021e). *Elliott 2021 Census Aboriginal and/or Torres Strait Islander people QuickStats* https://abs.gov.au/census/find-census-data/quickstats/2021/ILOC70700401

Australian Bureau of Statistics, A. (2021f). *Torres Strait Islands: 2021 Census All persons QuickStats* https://abs.gov.au/census/find-census-data/quickstats/2021/315011402

Australian Bureau of Statistics, A. (2021g). *Utopia - Arawerr - Arlparra 2021 Census Aboriginal and/or Torres Strait Islander people QuickStats* https://abs.gov.au/census/find-census-data/quickstats/2021/ILOC70901204

Australian Bureau of Statistics, A. (2021h). *Wutunugurra - Canteen Creek 2021 Census Aboriginal and/or Torres Strait Islander people QuickStats* https://abs.gov.au/census/find-census-data/quickstats/2021/IARE707006

Australian Bureau of Statistics, A. (2022). *Tennant Creek 2021 Census All persons QuickStats* https://abs.gov.au/census/find-census-data/quickstats/2021/SAL70251

Beal, C. D., Jackson, M., Stewart, R. A., Rayment, C., & Miller, A. (2018). Identifying and understanding the drivers of high water consumption in remote Australian Aboriginal and Torres Strait Island communities. *Journal of Cleaner Production*, *172*, 2425-2434. https://doi.org/https://doi.org/10.1016/j.jclepro.2017.11.168

Beal, C. D., Jackson, M., Stewart , R.A., Rayment C., Miller, A. (2018). Identifying and understanding the drivers of high water consumption in remote Australian Aboriginal and Torres Strait Island communities. *Journal of Cleaner Production 172*(2018), 2425-2434. https://doi.org/https://doi.org/10.1016/j.jclepro.2017.11.168

Beal, C. D. a. S., R.A. (2011). *South East Queensland Residential End Use Study: Final Report*. U. W. S. R. Allianc. file:///C:/Users/geoff/Downloads/UWSRA-tr47.pdf

Beal, C. D. J., M.; Stewart, R.A.; Fielding, K.; Miller, A.; Tan, PL. . (2019). *Exploring community-based water management options for remote Australia. Final report for the Remote and Isolated Communities Essential Services Project*. G. University. file:///C:/Users/geoff/Downloads/Remote-community-water-management-Beal-et-al-2019-Final-Report-1.pdf

Bureau of Meteorology. (2022). *Climate statistics for Australian locations Summary statistics Horn Island* http://www.bom.gov.au/climate/averages/tables/cw_027058.shtml

Bureau of Meteorology and CSIRO. (2022). *State of the Climate 2022*. http://www.bom.gov.au/state-of-the-climate/2022/documents/2022-state-of-the-climate-web.pdf

Butler, T., Anderson, K., Elder-Robinson, E., Ngampromwongse, K., Garvey, D., & Garvey, G. (2024). Indigenous Research Methods and Methodology. In G. Garvey (Ed.), *Indigenous and Tribal Peoples and Cancer* (pp. 295-300). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-56806-0_62

Central Australian Aboriginal Congress. (2022). *Response to the Northern Territory Strategic Water Plan: Directions Paper*.

Central Land Council. (2022). *The Struggle for Good Quality Drinking Water in Alpurrurulam* (Case Study For WSAA Report: Closing The Water For People And Communities Gap Improving Water Services To First Nations Remote Communities Issue. W. S. A. o. Australia. https://www.wsaa.asn.au/sites/default/files/publication/download/Closing%20the%20gap%20case%20study%20FA02%20WEB%20.pdf

CLC. (2020). *Submission to the National Water Reform Productivity Commission, https://www.pc.gov.au/__data/assets/pdf_file/0003/255729/sub035-water-reform-2020.pdf (accessed 8/11/24)*.

CoastAdapt. (2022). *Sea-level rise and future climate information for coastal councils* https://coastadapt.com.au/sea-level-rise-information-all-australian-coastal-councils#QLD_TORRES_SHIRE

Connor, J. D., Daniel Hill, D., Gregg, D., Sangha, K. (2022). *Review of the Singleton Horticulture Project's water entitlement provision costs, benefits and employment impacts.* . https://www.clc.org.au/files/Singleton-Irrigation-Project-Economic-Analysis-Report-FINAL.pdf

Cross, J. (2022, 8/11/2022). Northern Territory community's clean water struggle opens eyes on billion dollar issue facing Aboriginal communities. *National Indigenous Times*.

https://www.nit.com.au/northern-territory-communitys-clean-water-struggle-opens-eyes-on-billion-dollar-issue-facing-aboriginal-communities/

Davidson, H., Adam Morton, A., Molan, L. (2020). *Inside Australia's climate emergency: the killer heat*. The Guardian. https://www.theguardian.com/environment/ng-interactive/2020/feb/27/killer-heat-how-a-warming-land-is-changing-australia-forever

Evans, L. (2016). *Groundwater Overlying the Beetaloo Sub-basin: Explanatory Report, https://frackinginquiry.nt.gov.au/submission-library?a=456121 (accessed 31/10/24)*.

Frank Jupurrurla, N. (2022). *Community concern about water quality in Tennant Creek, NT, personal communication (December 5, 2022), speaking with Geoff Evans*.

Hall, N., Lee, A., Hoy, W., & Creamer, S. (2021). Five enablers to deliver safe water and effective sewage treatment to remote Indigenous communities in Australia. *Rural Remote Health*, *21*(6565). https://doi.org/https://doi.org/10.22605/RRH6565

Hall, N. L. (2020). *Pilyii Papulu Purrukaj-ji (Good housing to prevent sickness): A study of housing, crowding and hygiene-related infectious diseases in the Barkly Region, Northern Territory*.

Hall, N. L., Abeysuriya, K., Jackson, M., Agnew, C., Beal, C. D., Barnes, S. K., Soeters, S., Mukheibir, P., Brown, S., & Moggridge, B. (2022). Safe water and sanitation in remote Indigenous communities in Australia: conditions towards sustainable outcomes. *Australasian Journal of Water Resources*, *26*(2), 187-198. https://doi.org/10.1080/13241583.2022.2083052

Hall, N. L., Barnes, S., Canuto, C., Nona, F., & Redmond, A. M. (2021). Climate change and infectious diseases in Australia's Torres Strait Islands. *Australian and New Zealand Journal of Public Health*, *45*(2), 122-128. https://doi.org/https://doi.org/10.1111/1753-6405.13073

Hall, N. L., & Crosby, L. (2020). Climate change impacts on health in remote Indigenous communities in Australia. *International Journal Of Environmental Health Research*. https://doi.org/10.1080/09603123.2020.1777948

Healthy Environments and Lives Network. (2021). *Climate Change and Aboriginal and Torres Strait Islander Health Discussion Paper*.

Infrastructure Australia. (2021). *Reforms to meet Australia's future infrastructure needs: 2021 Australian Infrastructure Plan*.

Jackson, S., & Altman, J. . (2009). Indigenous Rights and Water Policy: Perspectives from Tropical Northern Australia. *Australian Indigenous Law Review*, *13*(1), 27-48.

Kania, J., & Kramer, M. (2011). Collective Impact. *Stanford Social Innovation Review*, *9*(1), 36-41.

Kruse, P. D., Munson T.J. (2013). Wiso Basin In M. Ahmad, Munson, T.J. (Ed.), *Geology and mineral resources of the Northern Territory*. Northern Territory Government.

Lansbury, N., Moggridge, B., Creamer, S., Ireland, L., Buckley, L., Evans, G., Milsom, O., Pecl, G., & Mosby, V. (2023). *Aboriginal and Torres Strait Islander Peoples' voices and engagement in the Intergovernmental Panel on Climate Change: Advice to inform the Australian Government towards IPCC Assessment Report 7*.

Latimore, J. (2022, 26/9/2022). Historic legal win for Torres Strait Islanders over Australia's inaction on climate change, September 26. *Sydney Morning Herald*. https://www.smh.com.au/national/torres-strait-islanders-win-historic-human-rights-legal-fight-20220926-p5bl1y.html

Lea, T., Grealy, L., Moskos, M., Brambilla, A., King, S., Habibis, D., Benedict, R., Phibbs, P., Sun, C., & Torzillo, P. (2021). *Sustainable Indigenous housing in regional and remote Australia, AHURI Final Report No. 368, https://www.ahuri.edu.au/research/final-reports/368*.

Lowitja Institute. (2022). *Close the Gap Campaign Report 2022 - Transforming power: voices for generational change*. https://www.lowitja.org.au/content/Document/Lowitja-Publishing/ClosetheGapReport_2022.pdf

Maguire, M., & Delahun, B. (2017). Doing a Thematic Analysis: A Practical, Step-by-Step Guide for Learning and Teaching Scholars. *All Ireland Journal of Higher Education (AISHE-J)*, *Autumn*(3), 3351-3364.

Malhi, Y., Franklin, J., Seddon, N., Solan, M., Turner, M. G., Field, C. B., & Knowlton, N. (2020). Climate change and ecosystems: threats, opportunities and solutions. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *375*(1794), 20190104. https://doi.org/10.1098/rstb.2019.0104

McInnes, K., Abbs, D., Bhend, J., Chiew, F., Church, J., Ekström, M., Kirono, D., Lenton, A., Lucas, C., Moise, A., Didier Monselesan, D., Mpelasoka,F., Leanne Webb, L., Whetton, P. (2015). Wet Tropics Cluster Report, . In M. Ekström, Penny Whetton, P., Chris Gerbing, C., Grose, M., Webb, L., Risbey, J. (Ed.), *Climate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports*. CSIRO and Bureau of Meteorology,. https://www.climatechangeinaustralia.gov.au/media/ccia/2.2/cms_page_media/168/WET_TROPICS_CLUSTER_REPORT_1.pdf

McPherson, A., Brodie, R., Hostetler, S., Parige, R., Symington, N., Ray, A., & Halas, V. (2020). *Exploring for the Future—hydrogeological investigations in the Tennant Creek region, Northern Territory* (Record 2020/33). http://dx.doi.org/10.11636/Record.2020.033

Memmott, P., Lansbury, N., Go-Sam, C., Nash, D., Redmond, A., Barnes, S., Simpson, P., & Frank, P. (2022). Aboriginal social housing in remote Australia: crowded, unrepaired and raising the risk of infectious diseases. *Global Discourse*, *12*. https://doi.org/10.1332/204378921X16315375796362

Morey, K., Franks, C., Pearson, O., Glover, K., & Brown, A. (2023). Research ACCORDing to whom? Developing a South Australian Aboriginal and Torres Strait Islander Health Research Accord. *First Nations Health and Wellbeing - The Lowitja Journal*, *1*. https://doi.org/10.1016/j.fnhli.2023.100003

Moskos, M., Isherwood, L., Dockery, A. M., Habibis, D., Grealy, L., Benedict, R., Harris, M., Singh, R., & Lea, T. (2024). *Indigenous mobility and its impact on remote infrastructural needs: an exploratory study, AHURI Final Report No. 423, http://www.ahuri.edu.au/research/final-reports/423 (accessed 6/11/24)*.

NATSIWA, & UQ. (2020). *Central Desert women talk about their health, their housing and their Country (short film), https://youtu.be/-xnCMiO9oUM (accessed 7/6/23).* .

NESP Earth Systems and Climate Change Hub. (2018). *Climate change in the Torres Strait: implications for fisheries and marine ecosystems* (Earth Systems and Climate Change Hub Report No. 4,, Issue. N. E. S. a. C. C. Hub. https://nespclimate.com.au/wp-content/uploads/2016/03/ESCC-R004-TS-CC-fisheries-workshop-180601.pdf

NESP Earth Systems and Climate Change Hub. (2020). *Climate change in the Northern Territory: state of the science and cliimate change impacts*. NESP ESCC Hub. file:///C:/Users/geoff/Downloads/state-of-the-science-and-climate-change-impacts-final-report.pdf

Northern Territory Government. (2021). *Northern Territory Strategic Water Plan* (NTG, 2021. , Issue. P. a. W. S. Department of Environment. https://watersecurity.nt.gov.au/__data/assets/pdf_file/0010/1084879/Northern-Territory-Strategic-Water-Plan-directions-paper.pdf

NTG. (2021). *Singleton Station Water Extraction Licence Decision*. https://depws.nt.gov.au/news/2021/singleton-station-water-extraction-licence-decision

NTG. (2023). *Western Davenport Water Allocation Plan 2024–2027: Report 15/2023, https://nt.gov.au/__data/assets/pdf_file/0019/1422280/western-davenport-water-allocation-plan-2024-2027.pdf (accessed 6/8/24)*.

O'Donnell, E., Godden, L., & O'Bryan, K. (2021). *Cultural Water for Cultural Economies, Final report of the 'Accessing water to meet Aboriginal economic development needs' Project*. https://law.unimelb.edu.au/__data/assets/pdf_file/0008/3628637/Final-Water-REPORT-spreads.pdf

Office of the Auditor General Western Australia. (2021). *Delivering Essential Services to Remote Aboriginal Communities – Follow-up*. O. o. t. A. G. W. Australia.

https://audit.wa.gov.au/wp-content/uploads/2021/05/Report-25_Delivering-Essential-Services-to-Remote-Aboriginal-Communities-%E2%80%93-Follow-up.pdf

Priya, A. (2020). Case Study Methodology of Qualitative Research: Key Attributes and Navigating the Conundrums in Its Application. *Sociological Bulletin*, *70*(1), 94-110. https://doi.org/10.1177/0038022920970318

Productivity Commission. (2021a). *National Water Reform 2020, Inquiry Report no. 96*. https://www.pc.gov.au/inquiries/completed/water-reform-2020/report/water-reform-2020.pdf

Productivity Commission. (2021b). Securing Aboriginal and Torres Strait Islander people's interests in water. In *National Water Reform 2020 Inquiry, Report no. 96*. https://www.pc.gov.au/inquiries/completed/water-reform-2020/report/water-reform-2020-supportingd.pdf

Productivity Commission. (2021c). Urban water services: regional and remote communities. In *National Water Reform 2020* (Vol. Supporting Paper G). https://www.pc.gov.au/inquiries/completed/water-reform-2020/report/water-reform-2020-supportingg.pdf

Quilty, S., Frank Jupurrurla, N., Bailie, R. S., & Gruen, R. L. (2022). Climate, housing, energy and Indigenous health: a call to action. *Medical Journal of Australia*, *217*(1), 9-12. https://doi.org/https://doi.org/10.5694/mja2.51610

Quilty, S., & Jupurrurla, N. F. (2021). Climate change: A Wumpurrarni-kari and Papulanyi-kari shared problem. *Journal of Paediatrics and Child Health*, *57*(11), 1745-1748. https://doi.org/https://doi.org/10.1111/jpc.15740

Race, D., Mathew, S., Campbell, M., & Hampton, K. (2016). Understanding climate adaptation investments for communities living in desert Australia: experiences of indigenous communities. *Climatic Change*, *139*. https://doi.org/10.1007/s10584-016-1800-4

Rainbird, J. (2016). *Adapting to sea-level rise in the Torres Strait*. N. C. C. A. R. F. CoastAdapt. file:///C:/Users/geoff/Downloads/CS011_Adaptation_in_the_Torres_Strait%20(1).pdf

Randal, M. A. (1973). *Groundwater in the Northern Wiso Basin and Environs, Northern Territory* [Bulletin 123 013761]. A. Government. https://d28rz98at9flks.cloudfront.net/100/Bull_123.pdf

Robison, J., Cosens, B.A., Jackson, S., Leonard, K. , McCool, D. (2018). Indigenous Water Justice *Lewis & Clark L. Rev.* , *22*, 841-921. file:///C:/Users/geoff/Downloads/SSRN-id3013470.pdf

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research*, *104*, 333-339. https://doi.org/https://doi.org/10.1016/j.jbusres.2019.07.039

Standen, J. C., Spencer, J., Lee, G. W., Van Buskirk, J., Matthews, V., Hanigan, I., Boylan, S., Jegasothy, E., Breth-Petersen, M., & Morgan, G. G. (2022). Aboriginal Population and Climate Change in Australia: Implications for Health and Adaptation Planning. *Int J Environ Res Public Health*, *19*(12). https://doi.org/10.3390/ijerph19127502

Terrado, M., Bojovic, D., Octenjak, S., Christel, I., & Lera St. Clair, A. (2023). Good practice for knowledge co-development through climate related case studies. *Climate Risk Management*, *40*, 100513. https://doi.org/https://doi.org/10.1016/j.crm.2023.100513

Tickell, S. J. (2003). *Water Resource Mapping Barkly Tablelands* (23/2003). N. T. Government. https://frackinginquiry.nt.gov.au/__data/assets/pdf_file/0020/433235/Water-Resource-Mapping-Barkly-Tableland.pdf

Torres Shire Council. (2022). *Water and Sewerage*. https://www.torres.qld.gov.au/council-facilities/thursday-island/water-and-sewerage

Torres Strait Island Regional Council. (2016). *Water Management*. https://www.tsirc.qld.gov.au/our-work/water-management

Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *British journal of management*, *14*(3), 207-222.

UN-Water. (2013). *Water Security & the Global Water Agenda: A UN-Water Analytical Brief*. file:///C:/Users/geoff/Downloads/analytical_brief_oct2013_web.pdf

UN. (2015). *Transforming our world: the 2030 Agenda for Sustainable Development*. https://www.refworld.org/docid/57b6e3e44.html

UN. (2022). *Human rights to safe drinking water and sanitation of indigenous peoples: State of affairs and lessons from ancestral cultures* (Report of the Special Rapporteur on the human rights to safe drinking water and sanitation, Pedro Arrojo Agudo,, Issue. https://www.ohchr.org/sites/default/files/documents/issues/water/2022-11-04/A-HRC-51-24-Friendly-version-EN.pdf

UN Human Rights Office of the Commissioner. (2022, 23 September 2022). *Australia violated Torres Strait Islanders' rights to enjoy culture and family life, UN Committee finds* https://www.ohchr.org/en/press-releases/2022/09/australia-violated-torres-strait-islanders-rights-enjoy-culture-and-family

Vanweydeveld, E. (2022). *Closing the Water for People and Communities Gap: Improving Water Services to First Nations Remote Communities - Summary Report and Key Recommendations*. W. S. A. o. Australia. https://www.wsaa.asn.au/sites/default/files/publication/download/Closing%20the%20gap%20Summary%20FA01%20WEB_.pdf

Watterson I., A., D., Bhend, J., Chiew, F., Church, J., Ekström, M., Kirono, D., Lenton, A., Lucas, C., McInnes, K., Moise, A., Monselesan, D., Mpelasoka, F., Webb, L., Whetton, P. (2015). Rangelands Cluster Report, Climate Change. In M. Ekström, Whetton, P., Chris Gerbing, C., Grose, M., Webb, L., Risbey, J. (Ed.), *Australia projections for Australia's Natural Resource Management Regions: Cluster Report*. CSIRO and the Bureau of Meteorology,.

https://www.climatechangeinaustralia.gov.au/media/ccia/2.2/cms_page_media/168/RANGELANDS_CLUSTER_REPORT_1.pdf

Wyrwoll, P. R., Manero, A., Taylor, K. S., Rose, E., & Quentin Grafton, R. (2022). Measuring the gaps in drinking water quality and policy across regional and remote Australia. *npj Clean Water*, *5*(1), 32. https://doi.org/10.1038/s41545-022-00174-1